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Zero-Net Energy Building Science Research: Nebraska Housing Case Study

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Nebraska Housing Case Study

Timothy L Hemsath

Introduction

What makes a new home sustainable? There is no simple answer and no silver bullet to reducing energy consumption, choosing the right building material or perfectly designed floor plan. Every case is different and every home-owner has their own perspective. To answer the question I was motivated to assemble this mini-portfolio of homes to begin identifying current best practices.

This booklet contains five newly constructed Nebraska homes. Each example identifies what high performance green building design elements, technologies and systems builders, architects and home-owners are using. The following five homes are not all Nebraska has to offer as examples, but are a sample in order to help the next generation of new homes seeking to be energy efficient and sustainably designed a place to begin.

The format of each case study house begins with a short summary and partners involved in the project. The following pages identify and describe each homes features with a number and image. Not all the numbers will appear on the background image as the identified elements are not visible. Each case study can be printed and used individually or in tandem with others.

This research was part of a larger collaboration at the University of Nebraska involving faculty from various campuses and departments. I would like recognize the faculty Yong Cho, Peter Hind, Jim Goedert, Andrew Jameton, Richard Lomneth and George Morcous.

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The ALBRIGHT PLUS is a single-family residential single story home with conditioned basement and attached unconditioned garage. The foundation is cast in place concrete and 2x6 framed exterior wall, wood truss roof, with ducts located in wood floor trusses. It is situated in a cold climate. A cold climate is generally defined as a region with approximately 5,400 heating degree days (65°F basis) or more and fewer than approximately 9,000 heating degree days (65°F basis).

Hearthstone Homes has discontinued this particular house model used in research with the University of Nebraska. All Hearthstone Homes are ENERGY STAR qualified, achieving HERS index ratings in the mid to low 50s meaning they are 50% more energy efficient that a home of comparable size. The HERS index is a scoring system, the lower the HERS index the more energy efficient. A score of 0 would be a zero-net energy home.

HEARTHSTONE HOMES™

ALBRIGHT PLUS

OMAHA

1 *Roof Insulation*

Loose fill insulation is blown into the attic at a uniform depth (approx. 17") to achieve an R-50 insulation factor.

2 *Wall Insulation*

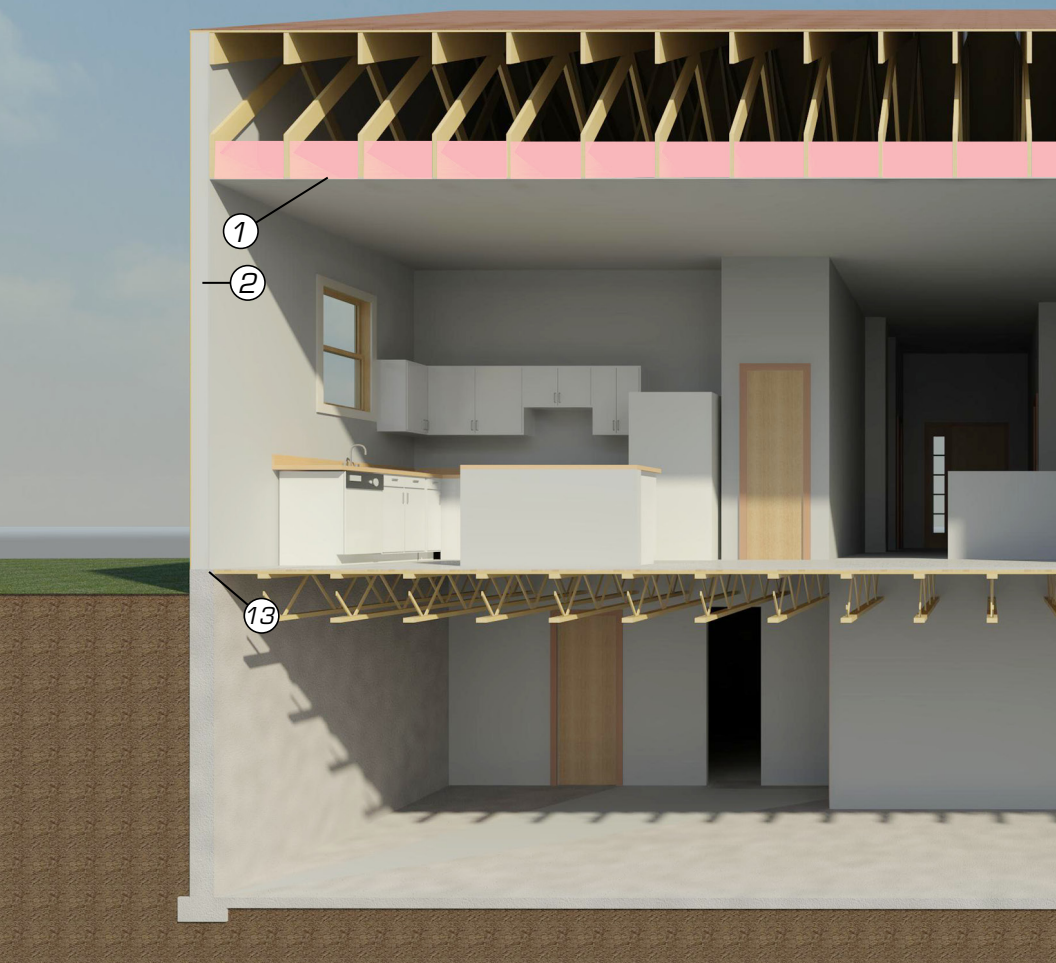
Bibs is a blown in wall insulation system where a netting is tightly stapled to the interior face of the studs. This allows the blown in installation of loose fill insulation into the stud space between the exterior sheathing and the interior netting.

3 *Garage Ceiling*

Garage ceilings below a living space are designed with a conditioned space just below the second story floor. The bottom of the floor truss is insulated with an R-30 fiberglass batt stapled to the bottom of the truss cord.

4 *Stairway Foam*

Rigid, foil-faced Styrofoam is applied to the foundation wall below stairs and landings where irregular spaces and reduced clearances are present. Styrofoam, 1-1/2"-2" thick, is installed as needed to meet the required insulation value.



5 *High Efficiency Windows*

Windows have a ¾" double pane glazing with solar cooling optimized low-E with argon gas fill for high performance. The spacer between glazing and frame is upgraded to provide a "warm edge".

6 *Insulation Encapsulation*

To achieve the best performance from wall insulation, it is important the insulation is encapsulated on all six sides to prevent air infiltration on all walls between conditioned and unconditioned space.

7 *Finished Basement Wall*

The optional finished or partial finished basement wall is a 2 x 4 wall with 2 x 6 plates placed inside the foundation walls. The stud cavities are filled with kraft-faced R-19 fiberglass insulation.

8 *Insulation at Slab Edge*

Homes with the optional walk-out basement are installed with a 2' section of R-10 rigid foam insulation on the inside face of the footing. The foam insulation extends from the top of the footing downward for 2'.

9 *Blanket Insulation*

Unfinished basement walls are insulated with a light density fibrous blanket laminated with a vinyl facing with an R-19 rating. This product has a superior thermal performance, is noncombustible, fire-rated and lightweight and covers the wall from the sill plate to the concrete floor.

(10) *Sealing Attic Access Panel*

The access to the attic is built up to provide a retaining barrier against the full depth of blown attic insulation. The access panel is installed in a frame made with trim casing.

(11) *Sealing Drywall*

A continuous bead of glue is installed at the return air and top and bottom plates to ensure an air seal throughout the home.

(12) *Foam Draft Stops in Garage*

Draft stops are installed and insulated in the garage ceiling at the wall line when there is living space above.

(13) *Foam all Sills and Rim Joist*

Insulating spray foam is applied from the top few inches of the foundation wall, across the sill and continued up to the top of the intersection of the rim joist and the subfloor above.

(14) *Blow Duct Drop in Garage Full*

The unconditioned garage is insulated by loose fill insulation above the soffit area to provide protection for the supply and return air trunk lines.

(15) *Seal Wall Framing*

Joints in wall framing are a source of air infiltration, to mitigate this between the wall framing and subfloor, panel joints, and corners. Pure silicon caulking has proven the best sealant.

(16) *95% Efficient Furnace*

The Energy Star qualified Trane XR95 single stage furnace features a 95% AFUE rating.

(17) *Decrease Equipment Sizing*

Heating and air conditioning equipment is sized in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies. Ductwork is made substantially airtight and leak free and insulated when necessary.

ALBRIGHT PLUS

NEBRASKA RESEARCH INITIATIVE FUNDING

Interdisciplinary Building Science Research Partners:

- University of Nebraska-Lincoln College of Architecture
- Department of Chemistry at the University of Nebraska-Omaha
- University of Nebraska-Lincoln College of Architectural Engineering and Construction
- University of Nebraska Medical Center College of Public Health

Located in North Lincoln, NE the Archspace home was designed and built by students from the University of Nebraska - College of Architecture. The home was constructed for the first time home buyer program, Neighbor Works. The design of the home uses passive solar techniques, materials, and building methodology that are essential for sustainable design. The geothermal heating and cooling system in cooperation with other solar design decisions can provide natural ways of heating and cooling a home.

P A R T N E R S

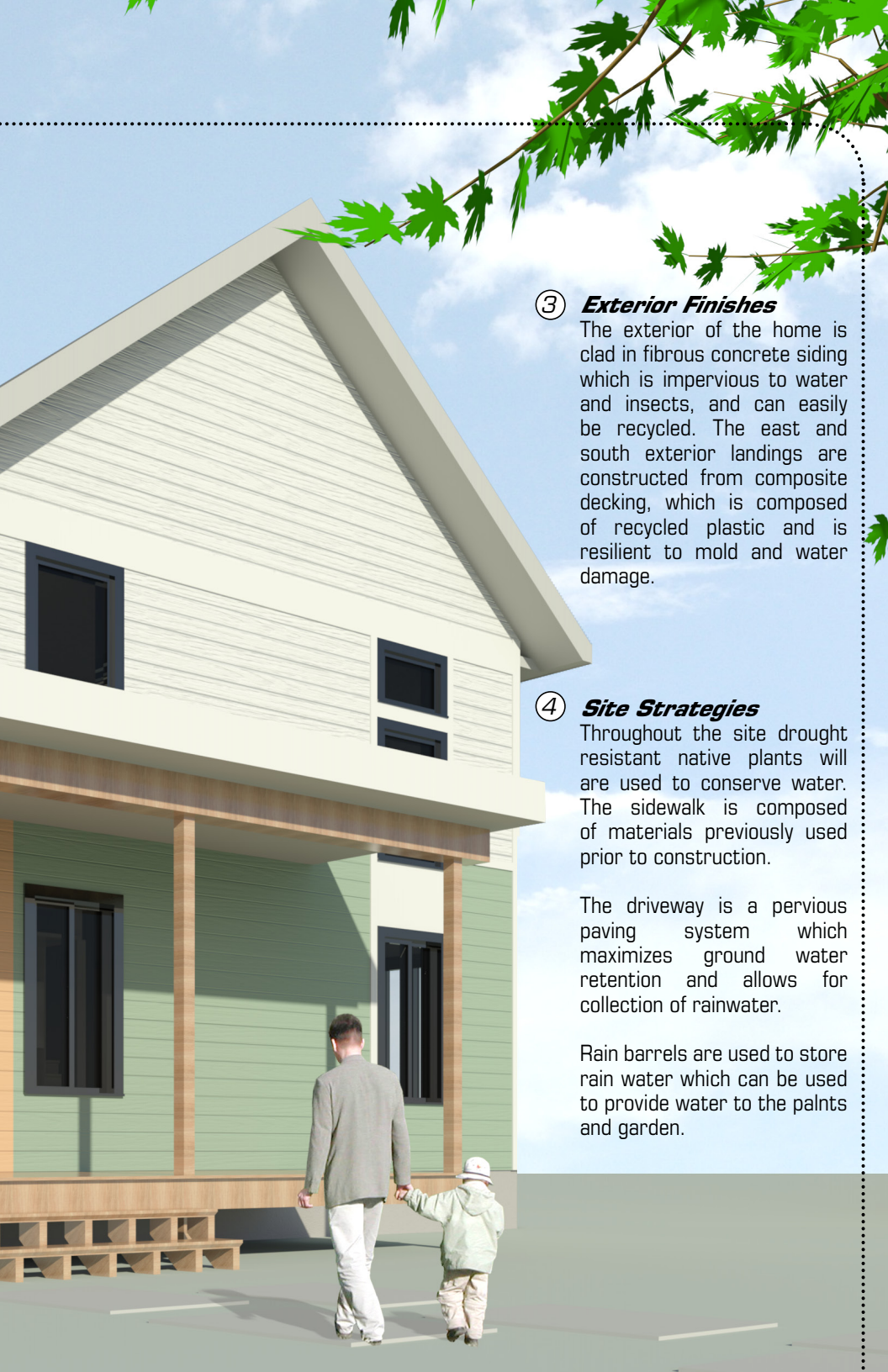
- NeighborWorks® America
- University of Nebraska-Lincoln
- UNL Architecture Students
- Nebraska Department of Economic Development
- City of Lincoln Housing and Urban Development
- State Farm Insurance
- Woods Charitable Fund
- Straw Sticks and Bricks
- Tech Masters
- Stephens and Smith
- EMO Flooring
- Crawford Plumbing
- Pella Windows

1 Solar Orientation

The solar shades and the gable roof are specifically sized so that during the long hot summer months the southern facing windows of the home will be in shade, protected from the harmful UV rays. While during the winter months the solar shades allow the suns rays to reach the interior so passive heating can utilized. Additionally the pitch of the roof is angled to allow solar panels to be installed if needed.

2 High Efficiency Doors and Windows

The use of air tight doors and windows allows for the HVAC system to operate at its highest efficiency. Windows are composed of double pane, argon filed, low-E coated glass.



③ *Exterior Finishes*

The exterior of the home is clad in fibrous concrete siding which is impervious to water and insects, and can easily be recycled. The east and south exterior landings are constructed from composite decking, which is composed of recycled plastic and is resilient to mold and water damage.

④ *Site Strategies*

Throughout the site drought resistant native plants will are used to conserve water. The sidewalk is composed of materials previously used prior to construction.

The driveway is a pervious paving system which maximizes ground water retention and allows for collection of rainwater.

Rain barrels are used to store rain water which can be used to provide water to the palnts and garden.

⑤ *Geothermal HVAC System*

A Geothermal heating and/or cooling system uses the earth's ability to store heat in the ground and/or thermal water sources. Under the home are vertical geothermal wells which provide 1.5 tons of heating / cooling loads for the home.

⑥ *Cork Flooring*

Cork has natural properties that are anti-allergenic and resistant to insects. A naturally occurring waxy substance in cork called suberin, is naturally fire resistant and doesn't release any toxic off-gassing. These natural properties plus the coatings used to seal cork flooring make it healthy and safe.

⑦ *LOW V.O.C. Paints*

V.O.C.'s are volatile organic compounds, these are toxins in typical household paints. Also 150 of the toxins have been linked to cancer, the lower the V.O.C the better indoor air quality.

⑧ *Wheatboard Cabinets & Recycled Counter tops*

Wheatboard cabinets were used in the kitchen and bathrooms, which use by-products from the processing of natural Midwest grain, and have are uera-formaldehyde free finish. The counter tops for the cabinets are made from post consumer recycled paper, glass, and plastic. The surfaces are durable and easy to clean, and because of their non-porous surface are resistant to stains and bacteria. Recycled plastic used in the carpet removes the toxic chemicals needed to process traditional carpet, which reduces the amount of V.O.C's found in carpet.

⑨ *Loft Space*

This lofted space can be easily be converted to a bedroom which allows flexibility in the years to come.

ARC—SPACE

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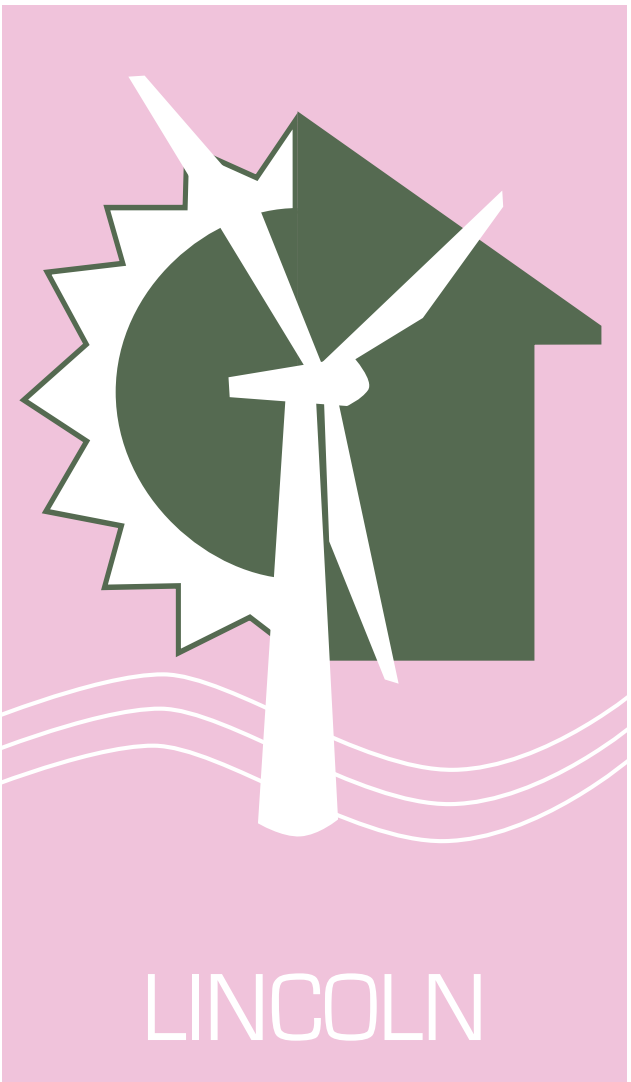
- University of Nebraska-Lincoln College of Architectural Engineering and Construction
- University of Nebraska Medical Center College of Public Health

Located in SW Lincoln, the Madison was designed by Authenticity LLC, and constructed by Rezac Construction. The Madison home will produce its own electricity through a 9 Kw photovoltaic system. The Madison utilizes the temperature of the earth for heating and cooling through a geothermal system.

In addition to efficient heating and cooling a tight seal from the exterior is provided by air tight windows, doors, and a superior insulated building. Fresh air ventilation with energy recovery system is utilized to provide clean air into the home. Throughout the house extensive applications of recycled products have been used, in place of conventional materials.

P A R T N E R S

- Mike Rezac, Rezac Construction
- Michelle Penn, Authenticity, LLC
- LES (Lincoln Electric System)
- Nebraska Energy Office
- NPPD (Nebraska Public Power District)
- Carrier
- Ecostar
- General Electric
- Pavstone
- Andersen Windows
- Dryvit System Inc.



THE MADISON

LINCOLN

1 Framing

The rafters are manufactured trusses with additional support added on site for the solar panels. The trusses have an 'energy heel' which allows the high insulation value to be continuous along the exterior walls. The 'flash and batt' method used in the attic gives a combined R-value of 57 to 64.

2 Roofing

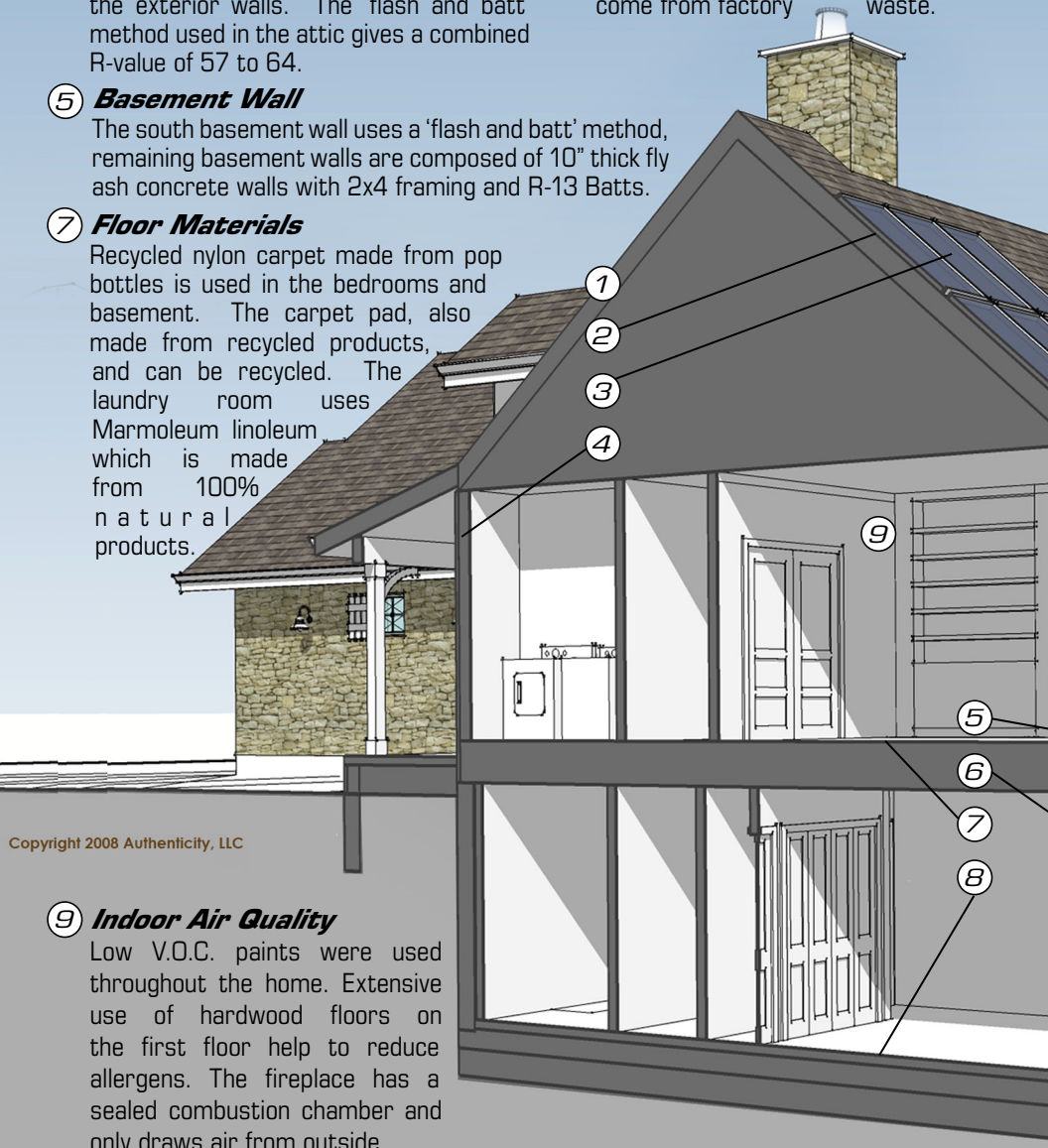
The roofing material is made from a recycled product called EcoStar. The slate looking shingles are composed of 80% recycled post-industrial rubber and plastic. The rubber and plastic come from factory waste.

5 Basement Wall

The south basement wall uses a 'flash and batt' method, remaining basement walls are composed of 10" thick fly ash concrete walls with 2x4 framing and R-13 Batts.

7 Floor Materials

Recycled nylon carpet made from pop bottles is used in the bedrooms and basement. The carpet pad, also made from recycled products, and can be recycled. The laundry room uses Marmoleum linoleum which is made from 100% natural products.



9 Indoor Air Quality

Low V.O.C. paints were used throughout the home. Extensive use of hardwood floors on the first floor help to reduce allergens. The fireplace has a sealed combustion chamber and only draws air from outside.

A passive radon venting system is installed through a sealed sump pump pit and is vented to the exterior.

3 *Renewable Energy*

On the roof are 48 BP panels supplying the electricity for the 9kw system. Our home is grid-tied through Norris Public Power District (NPPD) with net metering. A Fronius grid tied inverter was used. If the system is producing more energy than needed, the meter itself runs backwards and sends the electricity to NPPD. If more energy is needed due to a cloudy day, then NPPD would provide the additional energy needed.

4 *Wall Type*

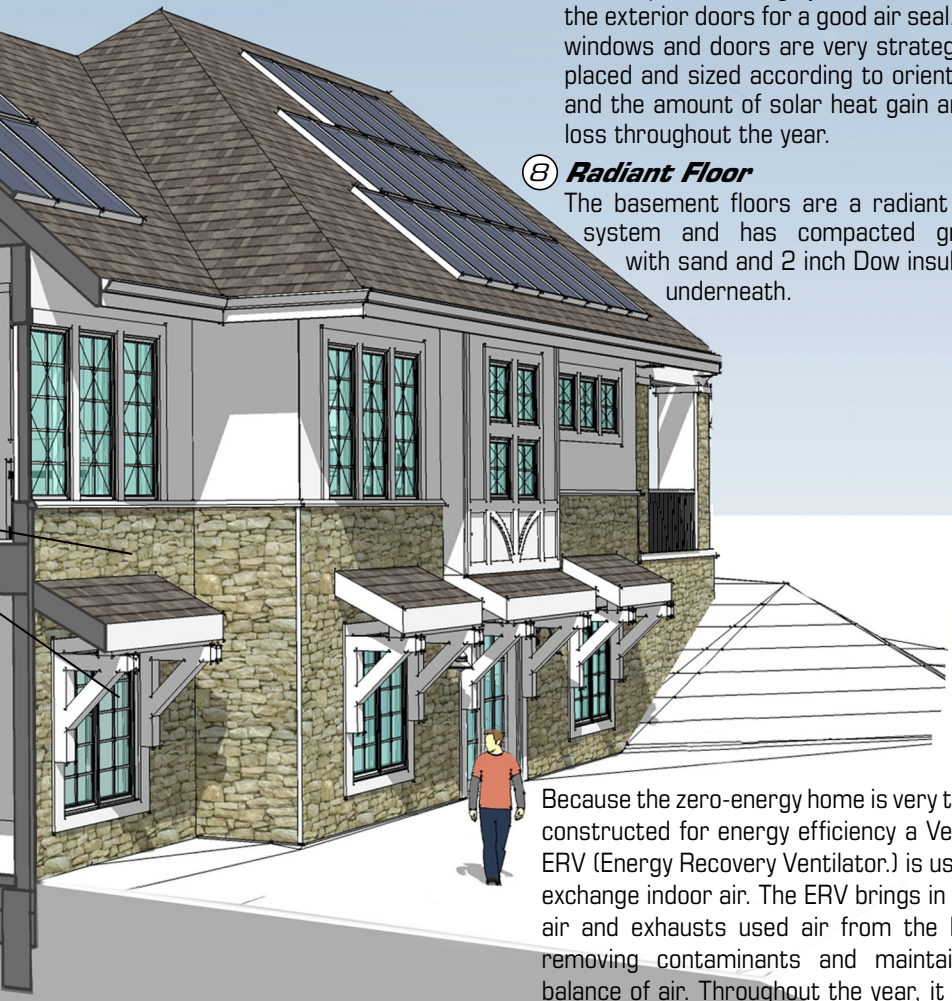
The walls were constructed with 2x6 studs at 16 inches on center allowing room for additional insulation. The 'flash and batt' method, allows an R-value from 23.5 to 27. This system is composed of one and a half inches of closed cell, high density sugar beet based foam with R-13 Batts.

6 *Windows and Doors*

The windows are dual-pane Low E4 glazing and argon filled and have U-factor of .31. A three point latching system was used on the exterior doors for a good air seal. The windows and doors are very strategically placed and sized according to orientation and the amount of solar heat gain and loss throughout the year.

8 *Radiant Floor*

The basement floors are a radiant floor system and has compacted gravel, with sand and 2 inch Dow insulation underneath.



Because the zero-energy home is very tightly constructed for energy efficiency a Venmar ERV (Energy Recovery Ventilator.) is used to exchange indoor air. The ERV brings in fresh air and exhausts used air from the home removing contaminants and maintains a balance of air. Throughout the year, it helps to regulate the humidity and temperature.

(10) *Site Strategies*

Conservation of water to the exterior by planning two different rain barrels into the gutter system. Native plantings and grass were used to reduce long term maintenance issues. The driveway is a pervious stone driveway that allows the water to drain directly into the ground.

(11) *Passive Design*

The basic form of the home is compact and linear along an East to West axis. This allows the utilization of the passive gain from the southern sun during the winter months and maximizes efficiency of the solar panels. The roof angle is a 10/12 slope for maximum solar access. The overhang extends out to two feet-six inches, ideal to shade the strong summer sun, yet allow for the winter sun to penetrate the interior.

(12) *HVAC System*

The Bridges, where this home is located, is the first total Geothermal Neighborhood in Nebraska. This means that each home is heated and cooled with help from the ground and/or water. The geothermal system requires no combustion process and stops the release of one ton of greenhouse gas. For each home on the water, there is a plate (4'x6' for this home) that will be submerged in the water. Each and every duct run and joint is sealed increasing the efficiency of the system. Air is supplied through the first floor trusses and none of the ductwork is located in the attic space.

(13) *Control System*

The whole-house control is a GE panel system and monitors the house function, located conveniently in the living room area. The system monitors the actual electrical usage of the home and the actual output of the photovoltaic panels at that moment and then can show daily, monthly or even yearly usage. The GE panel also keeps track of water usage all the way from watering the lawn to interior toilet and faucet usage.

THE MADISON

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- University of Nebraska Medical Center College of Public Health

ZNETH

OMAHA

Situated east of the Peter Kiewit Institute in Omaha, NE is a 1,800 square foot home known as the Zero net Energy Test Home or ZNETH.

ZNETH project's goal is project to produce more energy than it consumes. Solar collection devices located on the roof allow the ZNETH project to collect soalr energy and convert it to electricity. A Geothermal system harnesses the earth's temperature to be used for heating and cooling during the respective months, and a wind turbine will be used to exchange Nebraska's windy conditions into energy.

PARTNERS

- Airlite Plastics/Fox Blocks
- Aksarben Heating & Cooling, Inc.
- Andersen Windows/ Millard Lumber
- Carrell & Associates, Inc.
- Carroll Distributing & Construction Supply, Inc.
- CJ&T Lighting
- CM's Custom Lawn & Landscape
- Control Management, Inc.
- DK&B Construction Specialties
- Double D Excavating
- Green Team Geothermal
- The Gutter Company
- Hensel Richards Constructors, Inc.
- Hotz Concrete Pumping
- Hydro Pump Co. – HVAC
- J&T Plumbing & Sons
- KPE Consulting Engineers
- MJ Electric Corporation
- Nucor Building Systems
- phDesign, LLC
- OPPD
- Uponor, Inc.
- Werner Enterprizes, Inc.

(1) *Honeywell Blade Tip Power Wind Turbine*

This wind turbine has virtually no vibration, or friction due to the lack of ball bearings in the design. This helps to reduce energy loss during operation. The vertical orientation allows for the wind to be captured from any direction, including up and down.

(2) *1 Kw Photo-Voltaic Laminate Panels*

PVLP's perform well in high temperature and low light conditions. The panels are light weight and flexible, weighing only one pound per square foot. The system adheres directly to flat surfaces without penetrations.

③ Standing Seem Steel Roof

The standing seam metal roof is weather tight and coated with a high reflective paint to reduce heat gain. The panels are installed with concealed clips which allow for thermal movement.

④ Porch Overhang

The porch overhang was specifically sized so that during the long hot summer months the southern face of the home will be in shade. While during the winter months the angle of the overhang allows for the sun to reach the southern wall to passively heat the home.

⑤ High Efficiency Doors and Windows

The use of air tight doors and windows allows for a HVAC system to operate at its highest efficiency. Windows are composed of double pane, argon filed, low-E coated glass with a U rating of 0.30

⑥ Insulated Concrete Forms

ICF wall system substantially improves the R-value of the walls. A standard 2x4 stud wall with batt insulation is R-11 compared to the ICF R-24. The permanent performance of the ICF wall system will not degrade over time due to the nature of materials. All materials used are non-toxic and stable in high moisture environments.

⑦ Site Strategies

Drought resistant native plants are used to conserve water on the site. Pervious paving materials are used on the steps and walkways. Permanent erosion control is achieved with a water garden.

The two underground cisterns collect rain water used to water the garden and landscape.

⑧ Infill Development

Building in a greater density existing urban neighborhood saves and prevents development of native and agricultural lands.

⑩ *Energy Management*

Using a real time monitoring system the ZNETH home will obtain information on how much energy is being consumed and produced. By utilizing Energy Star® appliances, low-flow shower heads and faucets, and dual-flush toilets conservation of water and electricity can be maintained without extra effort from the occupant.

⑪ *Milestone Recycled Glass*

Made from recycled glass and different resins makes it one of the greenest products on the market. Used in many different applications such as interior counter tops, tables, signs, window sills and even toilet partitions.

⑫ *Bamboo Flooring*

Bamboo flooring is extremely hard, highly moisture resistant, and a rapidly renewable material. Bamboo's advantage is that it matures to around 50 feet and can be harvested within 5 years and re-grows on the same plant.

⑬ *Energy Recovery Ventilator*

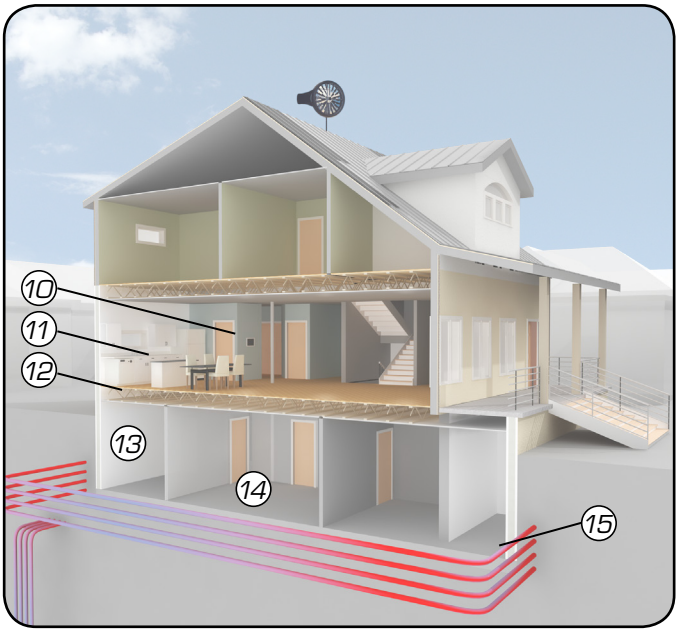
Capturing the exhausted building or space air and using it to precondition the incoming outdoor ventilation air is how an ERV meets ventilation & energy standards while improving indoor air quality, and reducing total HVAC equipment capacity. During the warmer seasons the system will pre-cool and dehumidify while humidifying and pre-heating in the cooler seasons.

⑭ *Indoor Air Quality*

V.O.C.'s, volatile organic compounds, are toxins found in interior materials. By using non-toxic finishes on all floors, walls, and cabinets these toxins are reduced. Using formaldehyde-free cabinet laminates and insulation helps to reduce the amount of off-gasing within the home. The absence of carpeting reduces indoor air particulates.

⑮ *Geothermal Energy*

A Geothermal heating and/or cooling system uses the earth's ability to store heat in the ground and/or thermal water sources. Two different loop orientations are installed, vertical and horizontal.



ZNETH

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- University of Nebraska Medical Center College of Public Health

University of Nebraska Lincoln

ZNETH II

OMAHA

The ZNETH II project is collaboration between the City of Omaha, Parks and Recreation and researchers at the University of Nebraska-Lincoln, Peter Kiewit Institute Technology Development Corp. Director of Parks, Recreation and Public Property, Melinda Pearson, said, “This caretaker residence is a great public partnership between the educational/ research component at the University of Nebraska and the recreation/summer camp activities in the City of Omaha. The 1,000 square foot, two-bedroom, one-bath home will serve as a research test facility for the University and will provide a caretaker residence for year-round occupancy at Hummel Park.” The project research goal is to provide the optimal energy efficiency at little to no additional construction cost.

City of Omaha, Nebraska
Incorporated February 2, 1857

City of Omaha
Parks & Recreation

The Nebraska Environmental Trust
preserving NATURAL NEBRASKA™ for future generations

The Peter Kiewit Institute

ZNETH II

Zero Net Energy Test House

OMAHA

1 *Ridge Vent*

A ridge vent was installed to allow the attic proper ventilation. During the summer months outside air flows through the soffit vents and exits the ridge vent which aids in keeping the temperature and moisture down in the attic.

2 *Absence of Roof Penetrations*

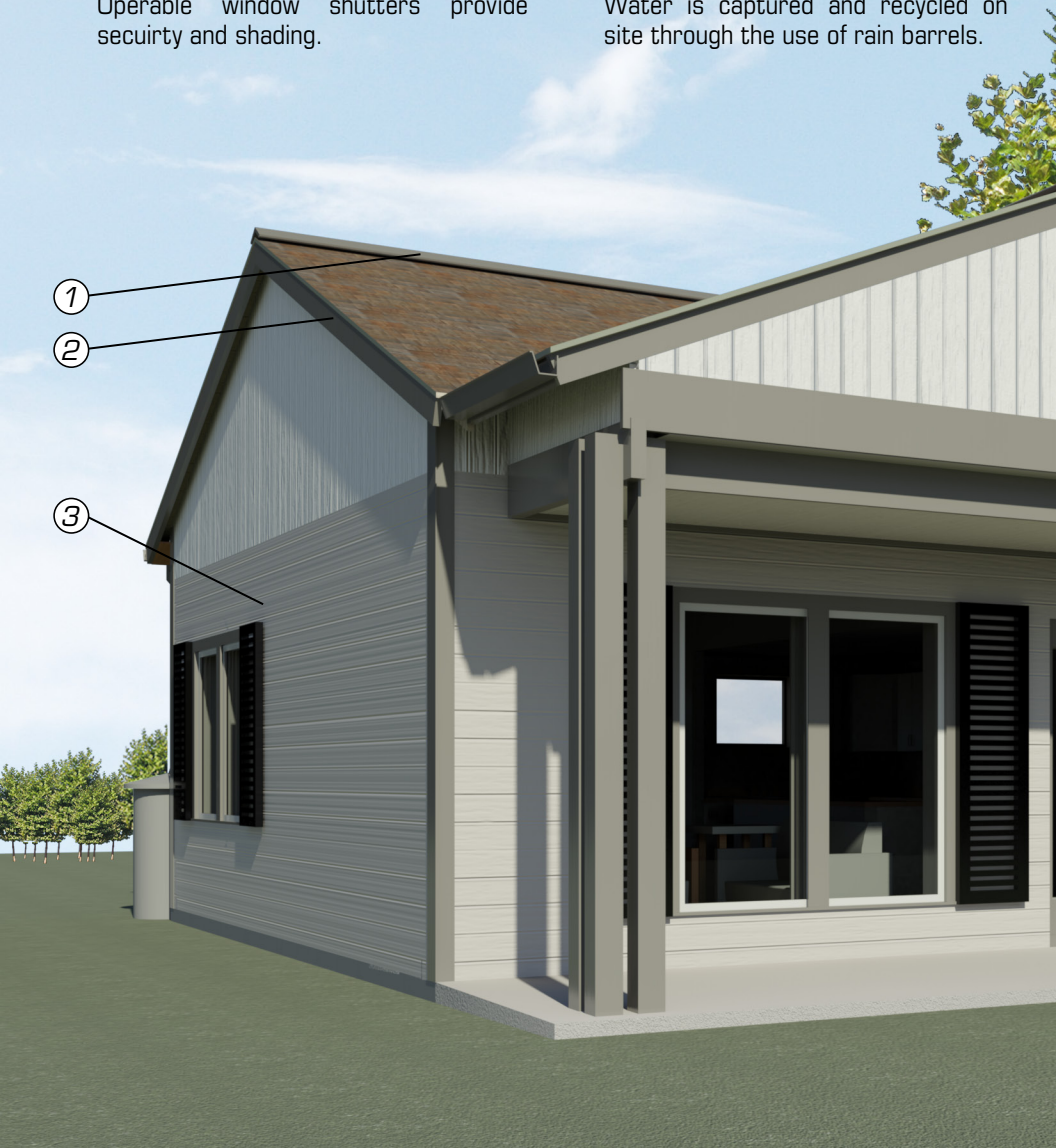
Roof penetrations can be minimized by the use of ventless plumbing techniques, such as air admittance valves, side wall vents, and direct vented appliances. By removing all penetrations heat loss will be reduced and water leaks minimized.

5 *Window Shutters*

Operable window shutters provide secuirty and shading.

6 *Water Conservation*

Water is captured and recycled on site through the use of rain barrels.



(3) *Hardiplank Siding*

Hardiplank siding is a fiber-cement siding composed of cellulose fibers and cement-like material. This siding material is extremely durable, sustainable, and fire resistant. If installed and maintained properly Hardiplank siding can provide an airtight barrier which can last over fifty years.

(4) *High Efficiency Doors and Windows*

The use of air tight doors and windows allows for a HVAC system to operate at its highest efficiency. Windows are composed of double pane, argon filed, low-E coated glass. These windows have a U value of 0.16 and a SHGC of 0.57 which is optimized to the house orientation for maximum performance.

⑤ *Whole House Energy Monitoring & Control System*

Using a real time monitoring system the ZNETH II home will obtain information on how much energy is being consumed and produced. Energy Star appliances, low-flow shower head, toilet and faucet conserve energy and water. Researchers will install occupancy sensors and lighting that optimized light performance based on occupant activity.

⑥ *R-50 Attic*

Loose fill insulation is blown into the attic at a uniform depth (approx. 17") to achieve an R-50 insulation factor.

⑦ *Roof truss with energy heel*

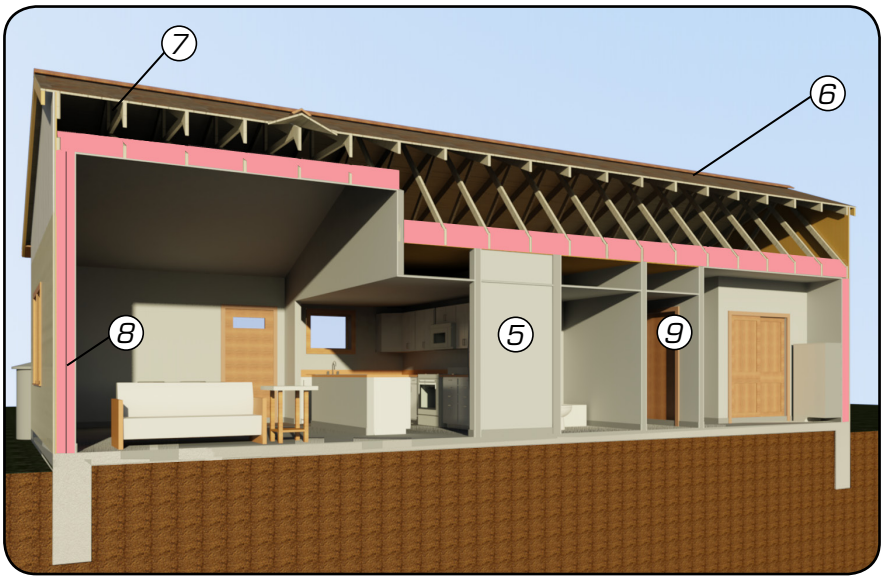
An energy heel lifts the roof to allow for additional insulation in the attic. Typical roof trusses narrow to 6" in thickness at the eave where the roof line meets the outer wall. As the roof gets narrower the effectiveness of the insulation is reduced due to less space. The advantage of including an Energy Heel in the roof trusses is it allows 14" of insulation versus the standard 6". This increases the R value of that area, and eliminates cold spots along the roof line.

⑧ *Double 2x4 studwall*

Double wall framing allows thermal isolation between inner and outer walls as well as eliminating the thermal bridging and air-barrier interruption of the floor deck. Using this technique along with insulation will achieve an R-30 value.

⑨ *Geothermal Heatpump*

Installed in the home is a 2 ton Geothermal heatpump, a two stage variable furnace blower combined with a hot water generator. A 5Kw backup heat and 6" fresh air intake. This system has an Energy Efficiency Rating of 26.



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Timothy L Hemsath is an Assistant Professor of Architecture
College of Architecture, University of Nebraska-Lincoln

http://archweb.unl.edu

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College of Public Health at the University of Nebraska Medical Center
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